SUMMER TREATMENT OF GREEN-HOUSE SOIL

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Agricultural Experiment Station

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BULLETIN 281

OHIO AGRICULTURAL EXPERIMENT STATION

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SUMMER TREATMENT OF GREENHOUSE SOIL

By W. J GREEN AND S. N. GREEN

For an interval of six to ten weeks during mid-summer vegetable greenhouses usually stand idle. Indoor tomatoes and cucumbers by the first week in July are usually past their prime and outside vegetables are so abundant that prices received for even the finest greenhouse products are relatively low. The houses are generally cleared at once of all growth, as it is no longer profitable to care for the crop, and at this stage disease and insects are at their worst, necessitating expensive operations if they are to be kept in check.

Unlike most florists, the vegetable greenhouse man does not consider it necessary to renew his soil annually. In large commercial ranges the cost of changing the soil amounts to a considerable sum, and if it can be avoided it means a large saving.

Generally, when the vines have been removed no further attention is given, the common opinion being that the intense heat under glass during July and August, together with the dryness of the soil, will destroy all insect life as well as fungi and bacteria.

This view is open to serious doubt. If vegetation is not completely removed from the the house, a few tufts of grass or weeds will support through the summer enough insects to restock in the fall. If the insects are driven or carried outside, with cooler weather and favorable conditions inside, they will some way find their way back. The various organisms of the soil do not seem, in general, to be adversely affected by the summer drying.* These, when such conditions prevail, quickly go into a resting stage, and in such a state are practically immune to any degree of heat and dryness that can be attained under ordinary greenhouse conditions. Not only this, but on resuming activity, they show a degree of vigor greatly exceeding, for a time, that before desiccation.

*Ohio Exp. Sta Cir. No. 69.

We too commonly think of the soil as a mass of dead, inert material. The real condition, so far as the top layer is concerned, and it is the upper six inches with which we are mainly interested, is that it is teeming with life, having a fauna and flora of its own, microscopic to be sure, but exceeding in activity and numbers the higher forms of life with which we are more familiar.

Greenhouse soils, in particular, because of artificial climatic conditions, which are almost tropical, and because of their origin and treatment, present very complex conditions. That some greenhouse soils are richer in available plant food than the average barn yard manure* suggests some of the problems with which we have to deal.

In considering these problems we must keep clearly in mind two points, first the natural requirements of cultivated plants, and second, the soil conditions.

Considering briefly the various angles of the soil problems, we may, for convenience, divide the organisms of the soil into two classes. First the beneficial bacteria and second, the various higher forms which are injurious to the first, together with the various parasitic fungi. The beneficial bacteria are those which increase the fertility of the soil by the production of ammonia, fixation of nitrogen, etc. The injurious organisms are the protozoa, etc., which interfere with the beneficial bacteria and thus are factors in limiting the fertility of the soil. Between these two classes, under normal conditions, there is an equilibrium. Under greenhouse conditions this balance is often disturbed and the cultivated crop seriously affected.

The chemical contents of the soil present conditions of extreme complexity. In greenhouse soils are found conditions in many ways wholly unlike those of outdoor soils, and our knowledge of the latter can hardly be applied, except in a general way. One of the problems, at least, in many greenhouses is to keep the soil in a balanced condition as to fertilizing ingredients, rather than to increase any at the expense of the health of the plants. Greenhouse soils are usually made before placing in the benches and the question of their improvement afterwards is of minor importance.

Plants are sensitive to the physical condition of the soil in the greenhouse as well as out of doors. It is difficult to separate these various problems as they are so closely interlocked. Greenhouse soils are generally made from the soil upon which the houses stand or from that of the immediate neighborhood, so that the type of soil from which they are made must be taken into consideration.

*Mass. Exp. Sta. Rpt. 1913.

Under the subject of physical conditions must also be considered the soil moisture and temperature.

EXPERIMENTS IN SUMMER TREATMENT OF SOILS

To determine the practical difference between the various methods of treating the soil during the idle summer months, experiments were started in present form at the Ohio Station greenhouses in the fall of 1908. A center sub-irrigated, raised bed was devoted entirely to this work and divided into four plots which were given treatment as follows:

New soil plot. Each year, just before the crop was to be planted in the fall, the entire soil of this plot was removed and replaced with fresh soil. This soil was the regular sod compost, prepared as described elsewhere. The spring crop of tomatoes each year was given a light mulch of manure.

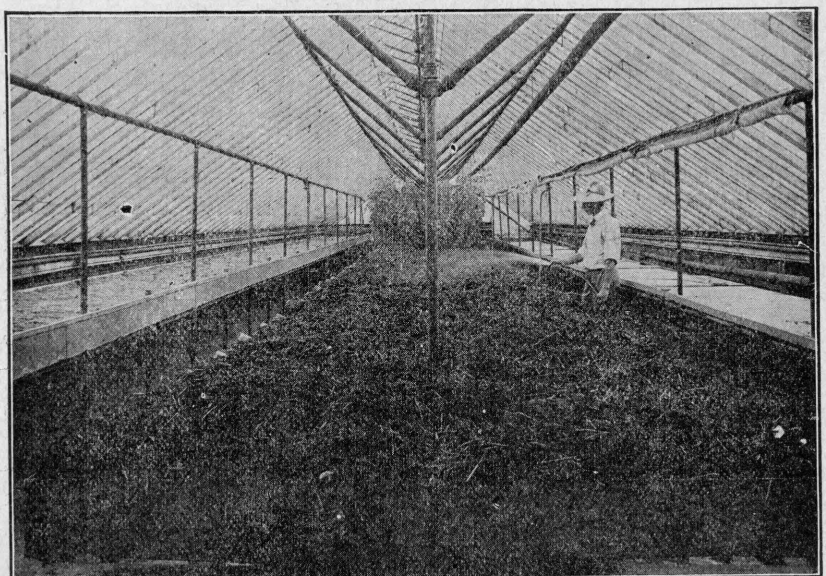

Fig. 1. Watering manure mulch.

Straw mulch plot. This and the succeeding plots were of soil having been cropped for at least three seasons, and given a summer mulch of manure and the same treatment as the manure mulch plot. The origin of this soil was sod compost. Immediately after the crop was removed each spring this plot was given a covering of from four to six inches of pure wheat straw. Both the straw mulch and the manure mulch plots were kept well watered during the summer and not allowed to become dry in any part. The watering was done on the surface as for a growing crop. Excessive watering must be avoided. Most of the straw was removed before preparing the bed for the fall crops, as it decayed but little and could not be worked into the soil. A covering of straw was given on the spring crop of tomatoes just as the fruit began to ripen.

Manure mulch plot. At the same time that straw was applied to the straw mulch plot a similar coating of coarse fresh manure was applied to this plot and watered at the same time. When ready for the fall crops this manure had been thoroughly leached and well decayed so that it could be spaded into the soil. This plot was also given a mulch of manure on the spring crop of tomatoes.

Dry plot. During the time between seasons in the summer this plot remained bare and unwatered. When ready to plant fall crops it was given a covering of fresh manure which was spaded into the soil. It was also given a mulch of manure on the spring crop of tomatoes.

The varieties of tomatoes in each plot were identical, Beauty and Stone being chiefly used. The Grand Rapids lettuce alone was used in lettuce crops.

The following table gives yields of fall crops of tomatoes:

FALL CROP OF TOMATOES

Average per plant in pounds and tenths.

Plot	1908	1909	1910	1911	1912	1913	Average
New soil	5.2	4.5	3.5	...	...	3.3	4.1
Straw mulch	4.9	3.2	3.1	..	.	2.5	3.4
Manure mulch	5.1	4.2	3.0	...	...	2.6	3 7
Dry	2.6	3.1	2.1	...	...	.9	2.1

A fall crop of tomatoes is not usually grown by Ohio greenhouse men, as average conditions are so adverse as to make very uncertain the yield, which is always much less than that of the spring crop and the prices obtained are not always so satisfactory. However, considering the very low prices prevailing for lettuce during recent seasons it should be given a larger planting. Seed for a fall crop is usually sown the first week of August and the first fruit ripens during the first half of December and continues through February, when the plants are removed to make room for the spring crop.

The discouraging conditions under which the fall crop is grown bring out distinctly the value of the various summer treatments, which, in the main, so far as the tomato crop is concerned, are in accordance with results obtained with spring crops. The new soil leads with a fair margin over the manure mulch and at no time was it exceeded. The straw mulch plot shows a rapid decline in yields. The dry plot at no time was a close competitor to the other plots and was the only one to show a seriously diseased condition of plants, which almost ruined last season's crop, bringing the average yield per plant down to less than half that of the new soil plot.

SPRING CROPS OF TOMATOES

Average per plant in pounds and tenths.

Plot	1909	1910	1911	1912	1913	1914	Average
New soil	9.4	7.7	7.2	11.8	8.6	6.1	8.4
Straw mulch	8.5	5.9	6.3	8.1	5.2	4.0	6.3
Manure mulch	9.1	6.2	6.9	10.2	6.6	5.4	7.4
Dry	7.1	7.0	6.4	9.1	7.1	4.2	6.8

The yield of the new soil plot, as with the fall crop, without exception stands in the lead. (See Chart No. 1.)

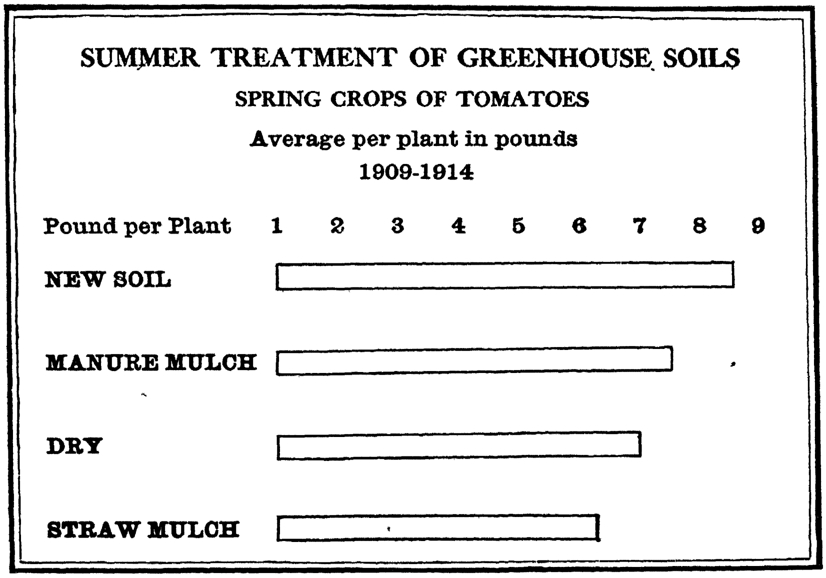

Chart No. 1. Showing results on tomato crop.

With the straw mulch plot there is a marked decrease below the new soil plot and the rate of decrease is fairly uniform from season to season, indicating a gradual exhaustion of the fertility of the soil and showing that the straw mulch itself is not sufficient to maintain plant food in the abundance demanded by the crop

Throughout the test this plot could be plainly distinguished because of its slower growth of plants and their light yellow foliage.

The manure mulch plot, while it did not excel the new soil plot in yield, shows at no time very great inferiority, and there is a question whether this possible loss is sufficient to warrant, for this crop, an annual renewal of the soil. From a mathematical standpoint, there is no margin between the probable errors of the figures of these yields, so that there is not sufficient ground for assuming that the yield of the new soil plot is superior to the manure mulch plot.

The yield of the dry plot, in spite of the fact that it received the same amount of manure as the manure mulch plot, indicates that the complete drying of the soil, even for the short period, seriously affects the yield of the tomato crop. This disastrous decrease was not alone due to lack of fertility, as during the last two seasons disease made serious inroads, this plot being the only one throughout the test to become badly affected by blight or wilt. The yields of the plot show that, so far as the tomato crop is concerned, it is essential to keep greenhouse soil supplied with moisture at all times, during summer, unless sterilization is practiced.

FALL AND WINTER CROPS OF LETTUCE

Average per plant in ounces and hundreths.

Plot	1911	1911-12	1912	1912-13	Average
New soil	3.24	4.32	3.33	3.32	3.55
Straw mulch	3.06	3.01	2.85	3.00	2 98
Manure mulch	3.74	4.61	4.11	4.29	4.18
Dry	3.29	5.25	3.86	4.05	4.11

A comparison of the relative yields of the tomato crops and those of lettuce shows plainly that the requirements of one of our greenhouse plants cannot be assumed as a standard for another. The weight of lettuce from new soil plots is less at any time than that grown on manure mulch and dry plots. The soluble plant foods in the older manured soils seem to be more favorable to the growth of lettuce. (See Chart No. 2.)

The weights on the manure mulch plot show a favorable annual increase on the average, hence one can safely assume that lettuce can be grown continuously on well manured old soil. The straw mulch plot shows a marked decrease which indicates, as with the tomato crop, that fertility in some available form must be added and that bacterial action cannot be depended upon to make available sufficient plant food.

The weights on the dry plot are practically the same as the manure plot yields. This is in direct contrast to the tomato yields on the same plots, and shows that desiccation of the soil does not affect the lettuce crop or that fresh manure has no deleterious effect on the growth of lettuce.

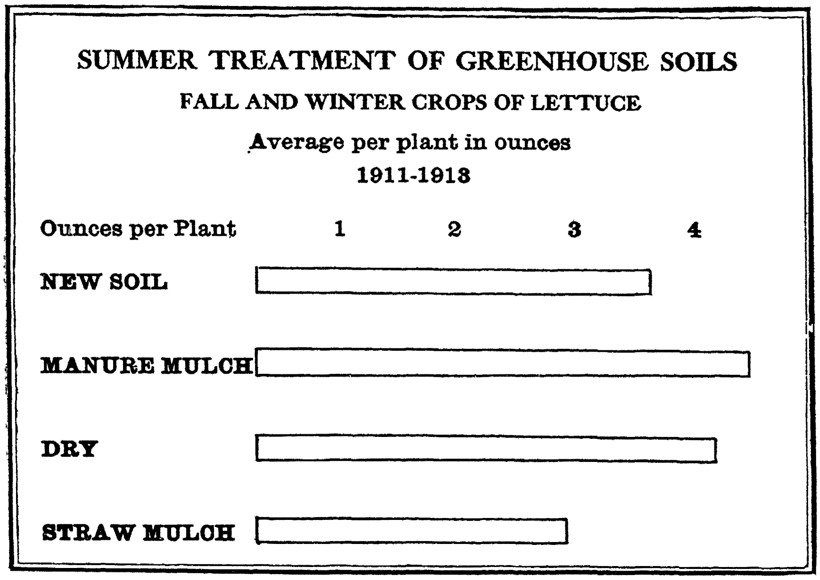

Chart No. 2. Showing results on lettuce crop.

The satisfactory growth of lettuce on old soil is more clearly brought out in the table given below, which shows the results obtained from a raised bench in an adjoining house, and on soil which has not been renewed for ten years, but had been given the summer manure mulch treatment. Two crops of lettuce were grown each season on this soil and though the soil was never sterilized the Grand Rapids lettuce was at no time affected by disease.

FALL AND WINTER CROPS OF LETTUCE

On soil not renewed for 10 years and with manure mulch treatment.

Average per plant in ounces and hundreths.

Crop of	1911-12	1912	1912-13	1913	1913-14	1914	Average
Average of 1200 plants.......	3.61	5.39	4.03	5.04	4.41	3.95	4.40

EXPERIMENTS WITH CUCUMBERS

No comparative experiments at these greenhouses have been made with the cucumber crop as to summer soil treatment, as with tomatoes and lettuce. The crop has been repeatedly grown on old soil which has been given manure mulch treatment, with variable results.

Results, however, obtained by other investigators tend to show that the cucumber is as sensitive as the tomato to the conditions prevailing in old well manured soils in the greenhouse, if not more so. Haskins[1] attributes the decrease in yields, after the first two or three seasons, to some physiological cause, brought about by malnutrition or over fertilization, and believes it to be directly due to an accumulation of soluble plant food, rather than to fungus or bacterial troubles. Extremely heavy applications of manure and commercial fertilizers were given the soils under investigation, as is common with the growers of that section, with the invariable result that trouble soon resulted if the soil was not renewed for the cucumber crop. The water soluble constituents of abnormal soils are shown to be three times those of normal hot house soils. No traces of disease were found on affected plants. To remedy this trouble thorough drainage is recommended and the replacing each year of a third to one-half of the old soil with fresh.

English investigators, Russell and Petherbridge[2], conclude that the "sickness" of greenhouse soils, as affecting the cucumber crop, is due to low bacterial efficiency as well as to an accumulation of insect and fungus troubles. The treatment recommended is partial sterilization by steam or antiseptics, which, by destroying protozoa, facilitate the activity of useful bacteria.

However much authorities may differ as to the cause of decreased yields of cucumbers and tomatoes under intensive greenhouse culture, the trouble is always associated with high organic and water contents as well as high temperature of soil, and usually such a decrease is certain. It is possible, in a degree at least, to check the causes of this decrease. Summer mulch, partial renewal or sterilization, combined with the best practical management, will accomplish this and thus avoid the expense of frequent renewal of soils for the tomato and cucumber crop.

SOIL STERILIZATION

It is during the idle summer months that sterilization is often undertaken, as well as between the lettuce crops. While no sterilization has been given the Station greenhouse soils under the summer mulch, it seems under most conditions essential before crops of

[1]Mass. Agri. Exp. Sta. Rpt. 1913.
[2]Jour. Agri. Science, Oct., 1912.

tomatoes or cucumbers and especially where the soil is allowed to dry during the summer Among the larger growers it is common practice but there seems to be a diversity of opinion as to times of application.

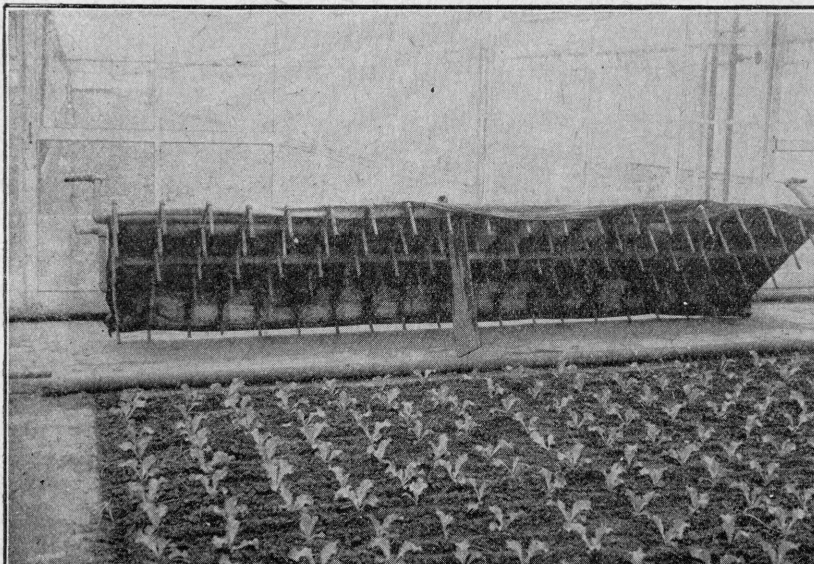

Fig. 2. Steam sterilizer for greenhouse soil.

There are two methods in common use at present, viz.: sterilization by steam heat and by formalin drench. For full discussion and instruction regarding these methods the reader is referred to a previous circular.*

In brief, sterilization consists in raising the temperature of the soil to about 200 degrees Fah. and maintaing it for an hour or more. This is accomplished by the use of perforated pipes in some shape or by an inverted pan. The former method consists in running perforated pipes through, or inserting them into the soil at regular intervals, covering and applying suitable pressure. The latter is a large, shallow pan which is inverted over the soil, leaving a small air space into which steam is forced. Soil in the seed or plant boxes is often sterilized by placing them in special rooms or cases into which steam is forced under pressure.

Formalin drench consists of an application of formalin at the rate of two pints to fifty gallons of water. The soil after being

*Ohio Exp. Sta. Cir. No. 57.

spaded is thoroughly soaked with this preparation and then allowed to partially dry out. It is not usually safe to set plants in soil thus treated for a week or ten days after treatment.

Steam sterilization results in the destruction of injurious fungi, protozoa, etc.,but also has other effects which are not without danger to the plants, as pointed out by Schreiner and Lathrop.* It is found to increase the water-soluble constituents and at the same time ammonia is formed. This is a direct cause of stimulation of growth which in the case of cucumbers and tomatoes may lead to mal-nutrition troubles. It increases the acidity of the soil, which leads to the necessity of liming, and if possible this should be done before sterilizing. Both beneficial and harmful compounds are produced, and when the latter overbalance the former the fertility of the soil is adversely affected.

The frequent use of steam sterilization should be avoided. It is an expensive operation and considerable skill and experience are necessary to its profitable use.

SOD COMPOST

Greenhouses demand a much richer soil than is usually found in even the best trucking types, and when a greenhouse is built usually some time passes before maximum yields can be obtained. It is essential that a greenhouse soil should contain an abundance of humus, which means future plant food, as well as that its mechanical condition be good.

The method used in preparing greenhouse soil at the Ohio Station and by many vegetable growers is the so-called "sod compost." Few of the larger growers have time or material to so prepare the soil for their ranges, but all can certainly prepare enough for use in seed and plant flats.

Its preparation is simple. A supply of good thick sod should be obtained. If bluegrass sod is not at hand, clover or timothy sod can be used as well or any soil in which there is an abundance of decaying vegetable matter. Muck or wood soils are especially desirable. Old greenhouse soils may be used if thoroughly weathered or if the compost is not intended for immediate use. Good fresh horse manure is desirable, though any available manure can be used, but the drier manures are to be preferred because of their higher calorific value, which results in the quicker decomposition of the mixture.

*U S. Bureau of Soils, Bul No 89

A convenient site is selected, an estimate of material made and foundations laid for a pile to be six to eight feet wide and about five feet high and of any desired length. A layer of about six inches of sod is placed, and on top of this about the same amount of manure, another layer of sod and so on until the pile is completed. (See Fig. 3.)

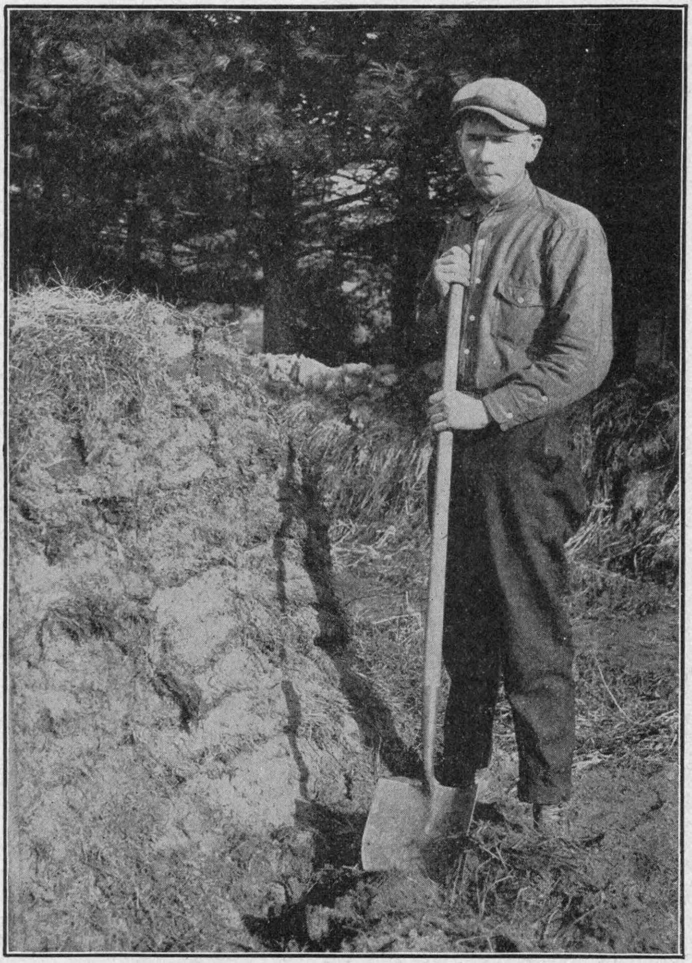

Fig. 3. Turning the compost pile.

The compost pile is generally built in the fall and allowed to stand over winter, when it is worked over, giving the manure and sod a thorough mixing. This forking over may be repeated as often as is necessary to make a fine mixture. The soil should be ready for the benches the following season. The compost heap can be made in the spring, and with care in keeping it moist and by frequent forking over it may be made ready for the greenhouse within six months, but a longer time is usually required.

MANURE FOR THE GREENHOUSE

The quantity of manure required for summer for mulch of tomato or cucumber crops and for spading into the soil between crops, is very large for any considerable range of houses. It is necessary to have a sufficient supply on hand at the right time and is highly desirable to have it in the best condition for application. It is customary to haul when conevnient and pile near the houses, using at once or after a time as needed. As manure becomes scarcer and higher priced, growers will be forced to adopt better methods than are now commonly in use.

Fig. 4. Applying manure in greenhouse.

Manure which is composted for a time before using is in better condition for greenhouse purposes. As the manure is hauled from the stable or car it is stacked in heaps about five feet in height and of any desired length or breadth. It is tramped down at once and watered heavily to prevent "fire fanging." As the manure decomposes it is forked over to assure uniformity in decay and to break up the long straws. When ready for use it is much reduced in bulk and in better shape to be worked into the soil.

European gardeners give their manures careful treatment and their methods are being adopted slowly in this country. Usually they have a special shed for their manure heap which is covered and with a water tight floor draining into a pit. The manure is watered and the leaching as collected in the pit is pumped back over the heap. A modification of this method is in use by a progressive Ohio grower, who has constructed a concrete floor for his manure. This is not covered, but the leachings are not lost as they seem to be reabsorbed by the top layers as they dry.

The value of manure in the greenhouse is not to be measured alone by the fertility added to the soil. As the manure decays it releases a certain amount of carbon dioxide which passing into the air is retained to a great degree in the confined space of the greenhouse. This gas is very essential to the growth of plants and if it can be increased the plant will make use of it up to a certain point,* as shown by investigations of Brown and Escombe.

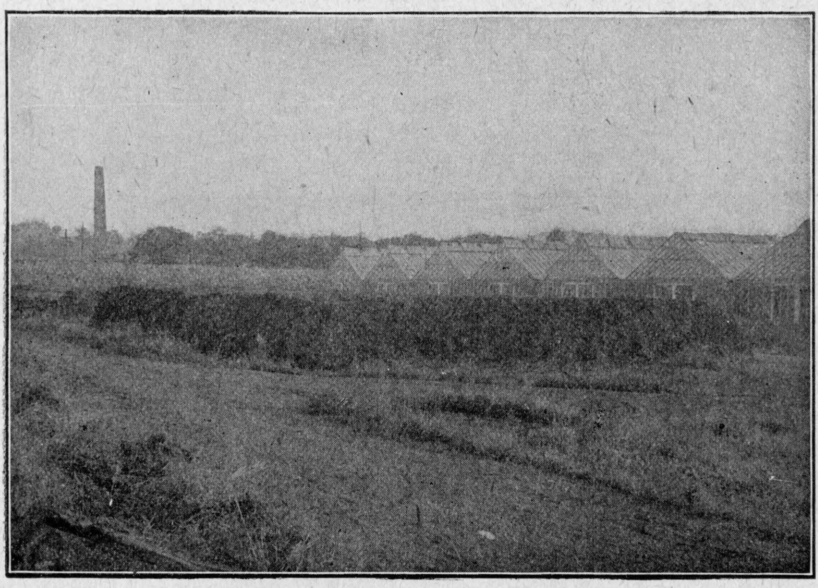

Fig. 5. Composting manure for greenhouse.

Manure is not a complete fertilizer, being deficient in phosphorus; hence, it is advisable to add this in some form of which acid phosphate is the most effective. 50 to 75 pounds of acid phosphate to a ton of fresh manure will greatly increase the value of the com-

*Pro. Royal Society, Vol. 76, 1902.

post as well as prevent the loss of some of the nitrogen. One of the effects of the use of acid phosphate is to hasten the maturing of the crop.

The continuous heavy application of manure to a greenhouse soil will, in time, almost completely change its character. Heavy soils will become light in texture and a sandy soil will become capable of holding an excessive amount of moisture. This fact should not be overlooked in the practical management of forcing houses.

COMMERCIAL FERTILIZERS

The application of commercial fertilizers to greenhouse soils is not a common practice and it is generally conceded that their use on good, well prepared composts is of little value.

Experiments conducted at this Station[1] show that the application of nitrogenous fertilizers to tomatoes, lettuce and radishes is without decided benefit when these crops are grown on sod compost. Extended experiments by Stewart[2] with Grand Rapids lettuce lead to the conclusion that to show results with commercial fertilizers a soil must be used that is somewhat deficient in plant food.

In experiments conducted to determine the relative value of commercial fertilizers and stable manure, Beach and Hasselbring[3] find that the use of commercial fertilizers without stable manure resulted in an increased yield but proved inadequate for forcing lettuce in a sufficiently short time to be profitable. The best crops were grown where the soil was fertilized with manure alone.

The use of commercial fertilizers is attended with many dangers and an indiscriminate application is almost certain to lead to disaster. An overdose of chemicals tends to inhibit root absorption, which in the greenhouse, where transpiration is very great, at times causes serious troubles. Very acid conditions are quickly brought about by the use of large amounts of fertilizers having acid constituents, and the effects of undesirable residues is a constant danger. Greenhouse soils are not subject to the leachings which heavy rains constantly give field soils, hence there is more danger from this source in the greenhouse than in the field.

LIME REQUIREMENTS

It is a common practice during the idle summer months to apply lime to greenhouse soils. The benefit, if any, derived from this practice depends upon the soil in question.

[1]Ohio Agri. Exp. Sta. Bul. No. 43.
[2]Indiana Agri Exp. Sta. Bul. No. 84.
[3]N. Y. Exp. Sta. Bul. No. 208.

Soils that contain large amounts of organic matter, such as all greenhouse soils should, require certain amounts of lime for the production of maximum crops. Nitrifying organisms, to do the most effective work, require soil conditions that are not excessively acid. Soils vary widely in their natural lime contents, a sandy soil being more benefited by an application of lime on the average than one of calcareous origin. Especially would one of the latter soils, when retained for a number of years and watered with hard water, not require an additional supply, as sufficient lime could be reasonably supplied from the water.

It must also be taken into consideration that plants vary widely as to lime requirements. Lettuce and cucumbers are reported to be benefited by lime, tomatoes are indifferent or slightly injured, while radishes are severely injurd by its application.

Ground limestone seems to be preferable to other forms for greenhouse use. It becomes available with comparative rapidity in such soils and the dangers from the use of caustic or hydrated forms are avoided.

SUMMER UTILIZATION OF GREENHOUSES

The suggestion is often made that the greenhouse might be used during the mid-summer months for growing crops, but as yet in Ohio such use has not been found practicable. The conditions in greenhouses are entirely controllable and it is quite possible to grow many of the heat loving or tropical vegetables, such as egg plant, peppers, squashes, etc., but most greenhouse men seem to desire a period of rest during mid-summer. Nearly all have some outside interests requiring attention at this period and help is in greatest demand at this time.

Cover crops can be grown during this period, but the cost of caring for them usually makes them too expensive, considering the relatively small amount of vegetable matter they add to the soil. The care in watering the summer mulch is much less and it adds much more organic matter to the soil.

SUMMARY

1. The common greenhouse crops of Ohio, tomato, cucumber, and lettuce require different soil conditions for maximum yields.

2. Lettuce can be grown continuously with safety on unrenewed manured soils.

3. Tomatoes and cucumbers are sensitive to conditions found in old soils and yields are quickly affected, demanding treatment or renewal of soils after two or three season's use.

4. The drying of the soil during the idle summer period seems to adversely affect the soil conditions for tomatoes but not for lettuce.

5. Summer manure mulch is recommended to check adverse soil conditions for tomatoes and cucumbers.

6. Summer mulch may not obviate the necessity of soil sterilization, but, in part, it appears to answer that purpose.

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